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(71) Applicant *(for all designated States except US)*: NKT TELECOM A/S [DK/DK]; NKT Allé 1, DK-2605 Brondby (DK).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : VIERECK, Peter, Johansen [DK/DK]; Dyssegårdsvej 82, DK-2860 Søborg (DK). MADSEN, Peter, Wieslander [DK/DK]; Ericaparken 29, St. C, DK-2820 Gentofte (DK).

(74) Agent: HOFMAN-BANG & BOUTARD A/S; Adelgade 15, DK-1304 Copenhagen K (DK).

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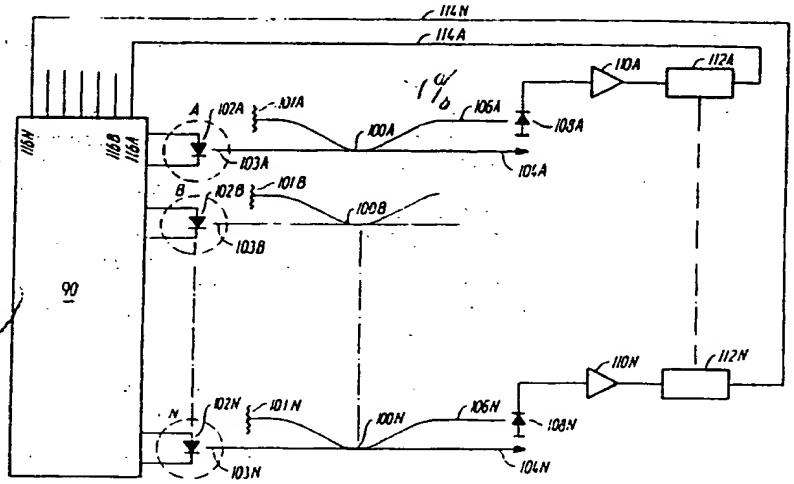

(57) Abstract

An optical fibre amplifier having one or more active fibres so coupled to an optical transmission line that each of the active fibres has at least one input for a pump signal. The active fibres are adapted to amplify an optical signal at a first wavelength at stimulated emission, when optical energy is added in the form of a pump signal at a second wavelength. The pump signals are provided by means of pump lasers adapted to emit energy at the second wavelength. The optical fibre amplifier has an optical combination network with a plurality of inputs coupled to respective pump lasers and adapted to receive energy from these. The outputs of the combination network are coupled to the pump signal inputs on the active fibres, said network being adapted to combine the optical energy added from the pump lasers so that the optical energy on each one of the outputs of the combination network originates from several pump lasers. Drop-out of a pump laser will cause the optical signal on several outputs on the combination network to be reduced, but complete drop-out of optical energy on an output is obviated.

+ DESIGNATIONS OF "SU"

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An optical fibre amplifier with coupling of pump energy from several pump sources

The invention concerns an optical fibre amplifier, and in particular the part that concerns coupling of pump energy from a plurality of pump sources.

The occurrence of optical fibre amplifiers is expected to involve a tremendous development within optical communications networks, since an optical component has been made available which is capable of amplifying an optical signal in an optical transmission path without having to generate electronic signals en route. Such optical amplifiers thus find application within many branches of optical communications systems. Optical fibre amplifiers may e.g. be used in a fibre-optical ringnet accessed by a plurality of transmitter/receiver units, and it may be used for increasing the distance over which a receiver can receive and re-form a signal from a transmitter. Here, it may e.g. be used as an in-line amplifier, it being positioned at a great distance from both transmitter and receiver. It is also possible to use an optical amplifier as a pre-amplifier of a receiver. Alternatively, it may be used as a booster amplifier, i.e. the fibre amplifier amplifies the optical signal immediately after it is transmitted from the transmitter.

Optical fibre amplifiers are usually made by doping an optical fibre with rare earths, such as erbium, during the manufacturing process. Amplification takes place addition of energy that excites electrons to a higher energy level. When stimulated with light energy from e.g. the arriving signal, the electrons will fall to a lower energy level, transmitting light at the frequency in question. This is analogous to the behaviour of a laser.

fig. 3 schematically shows a preferred embodiment of the structure of an optical fibre amplifier according to the invention,

fig. 4 schematically shows an alternative embodiment of an optical fibre amplifier according to the invention, and

fig. 5 schematically shows an embodiment of compensation circuits for use in an optical fibre amplifier according to the invention.

Fig. 1a shows a transmitter 5 which transmits an optical signal to a receiver 9 through an optical transmission line 6. For the distance between the transmitter 5 and the receiver 9 to be increased, the transmitted signal must be amplified en route. This is done by coupling a fibre end suitably spaced from the transmitter 5 into an optical fibre amplifier 7, which amplifies the signal and passes the signal thus amplified back to the transmission line 6 and further on to the receiver 9. To limit the noise from the optical amplifier, an optical bandpass filter 8 is positioned before a receiver 9. An optical fibre amplifier used in this manner is usually called an in-line amplifier. Fig. 1b shows an optical fibre amplifier used as a pre-amplifier, it being used for amplifying the optical signal on the transmission line 6 prior to signal detection. Since, here too, the noise is amplified by the optical amplifier, a bandpass filter 8 is positioned before the receiver 9. Fig. 1c shows an optical fibre amplifier used as a booster amplifier, said fibre amplifier being thus connected to the output on the transmitter 5.

Fig. 2 shows the structure of an optical fibre amplifier according to the prior art, where an optical signal is introduced via an optical transmission line 13 and coupled into an active fibre. Such an active fibre 12 may e.g. be

doped with erbium and have a length of typically 10-100 m. After amplification in an active fibre 12, an optical signal is again passed back to an optical transmission path 14. Analogous with the behaviour of a laser, amplification takes place by exciting electrons in an active medium to a higher energy level, from which the electrons can fall back to a lower energy level at stimulated emission, thereby transmitting light in a given wavelength range. This addition of energy is usually called pumping, and active pump sources 10 in the form of laser diodes are ordinarily used in optical fibre amplifiers. Energy from the pump sources 10 is coupled into the active fibre 3 through respective dichromatic couplers 11.

Fig. 3 shows an optical fibre network connecting four pump sources 20, 21, 22, 23 to four active fibres 30, 31, 32, 33, which are coupled in series (cascade coupling) and are adapted to receive an optical signal on an input 34, to amplify this signal and to apply the amplified signal on an output 35. Each of the pump sources 20, 23 emit optical power P, which will usually be the same for the four pump sources. This optical power will be marked by an index A, B, C, D below, so that the origin of the power will be visible from the expressions used. The output signal from the pump source 20 and the pump source 21, respectively, is passed to a fibre coupler 25 (3 dB coupler) designed so that there will be a signal with the power $(P_A + P_B)/2$ on each of the outputs of the fibre coupler. Correspondingly, a fibre coupler 26 divides the optical energy from the pump sources 22, 23, so that there will be an optical signal with the power $(P_C + P_D)/2$ on each of the outputs of the fibre coupler 26. Each of two additional fibre couplers 27, 28 receives a signal from respective outputs of the fibre couplers 25, 26, whereby the optical energy from each of the pump sources 20-23 is combined so that there will be an optical signal with the power $(P_A + P_B + P_C +$

3. An optical fibre amplifier according to claim 1 or 2, c h a r a c t e r i z e d by including at least one pump laser (20-23; 40-43) adapted to emit energy at a first polarization state, and including at least one further pump laser (20-23; 40-43) adapted to emit energy at a second polarization state.

4. An optical fibre amplifier according to claim 2, c h a r a c t e r i z e d by including at least one pump laser (20-23; 40-43) adapted to emit energy at a wavelength about λ = 1480 nm, and including at least one further pump laser (20-23; 40-43) adapted to emit energy at a wavelength λ = 820 nm or λ = 980 nm.

5. An optical fibre amplifier according to claim 1, c h a r a c t e r i z e d in that the optical combination network is a fibre-optical network.

6. An optical fibre amplifier according to claim 5, c h a r a c t e r i z e d in that the means (25-28; 45, 46) for combining the energy from the pump lasers (20-23; 40-43) comprise fibre couplers.

7. An optical fibre amplifier according to claims 1-6, c h a r a c t e r i z e d by including means (108A-N) for detecting an output signal from respective pump lasers (102A-N), and including means (112A-N) for determining the level of the output signal and for regulating the output signal of respective pump lasers (102A-N) in response thereto.

8. An optical fibre amplifier according to claim 7, c h a r a c t e r i z e d in that the detection means (112A-N) detect the presence of an optical signal from respective pump lasers (102A-N), and that the output signal level of the other pump lasers is increased if said signal is below a given threshold value.

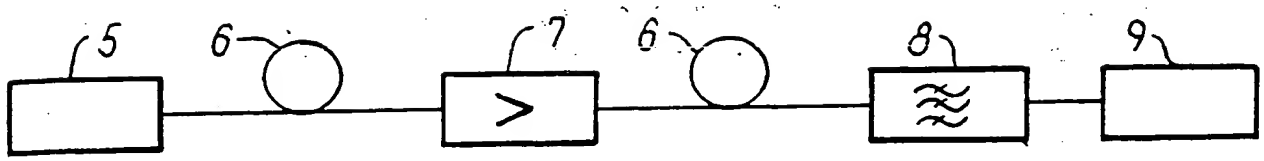

FIG. 1a

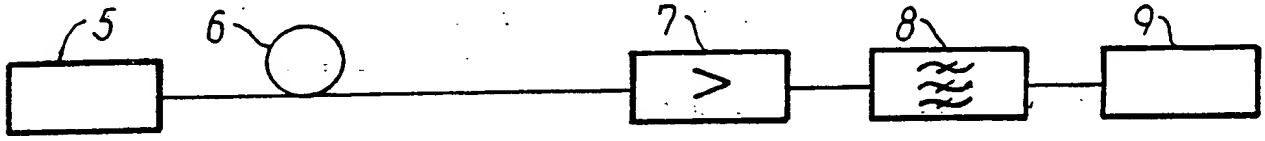

FIG. 1b

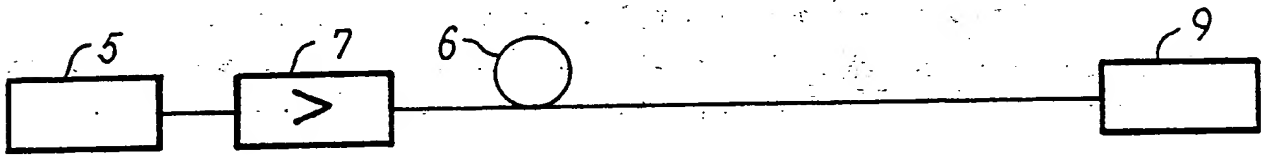

FIG. 1c

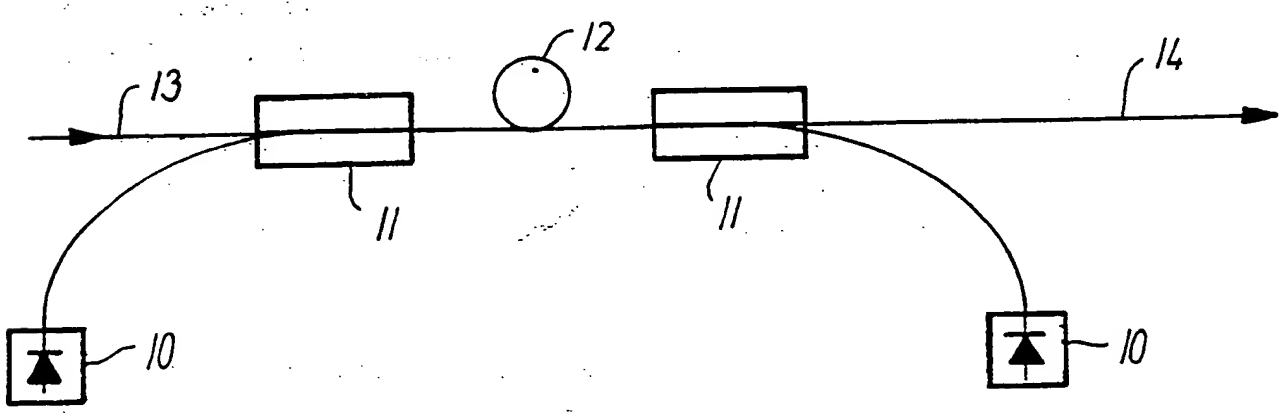

FIG. 2

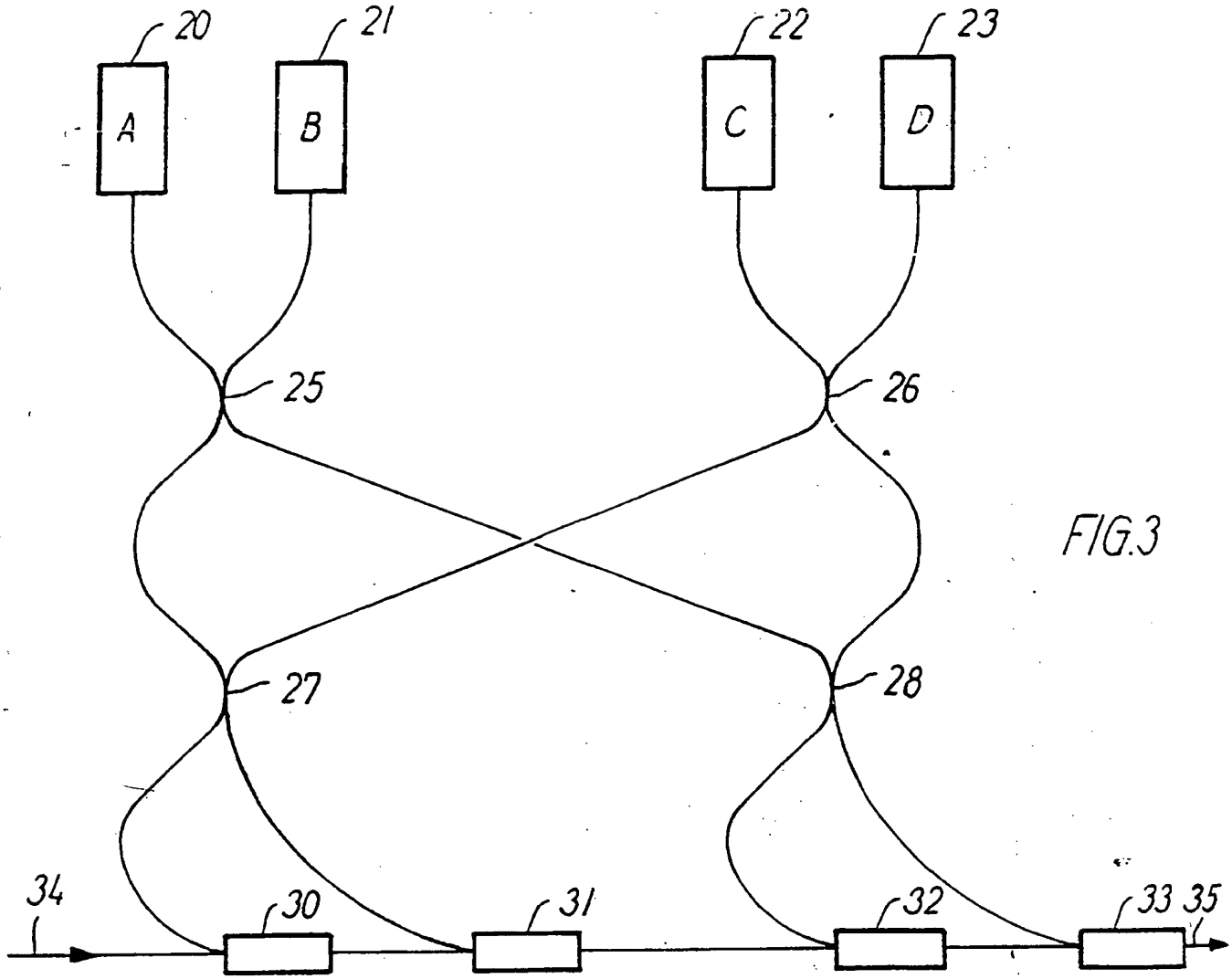
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FIG.3

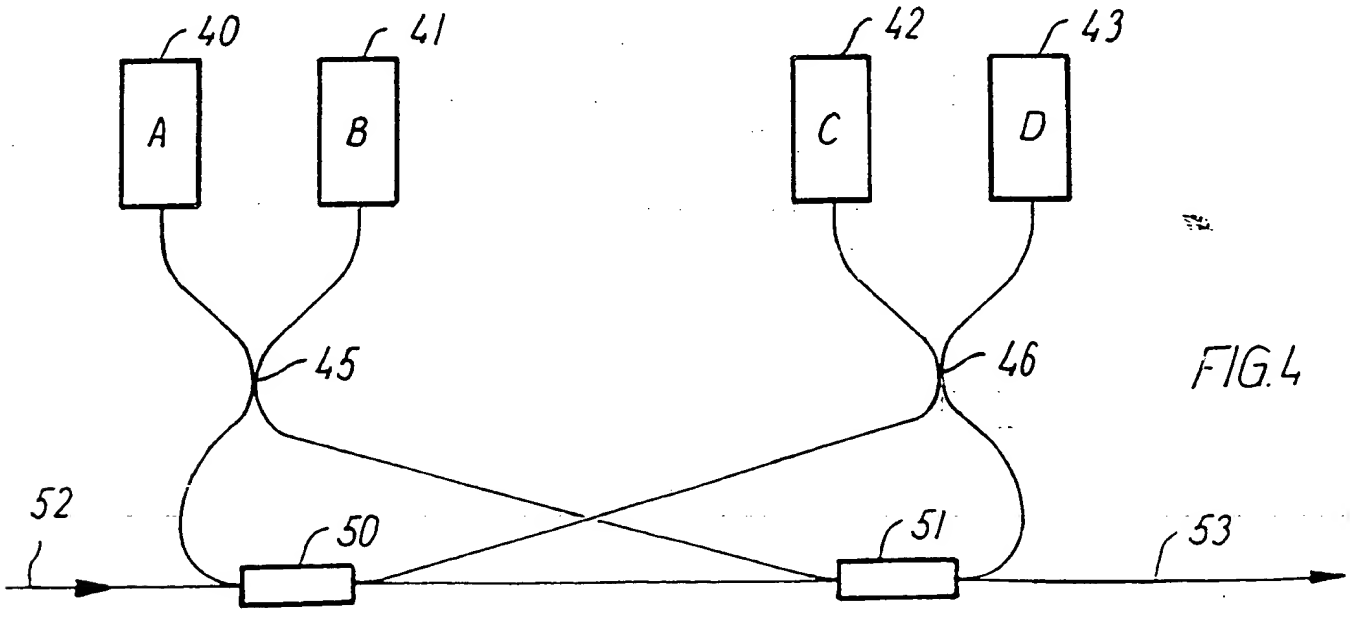
40
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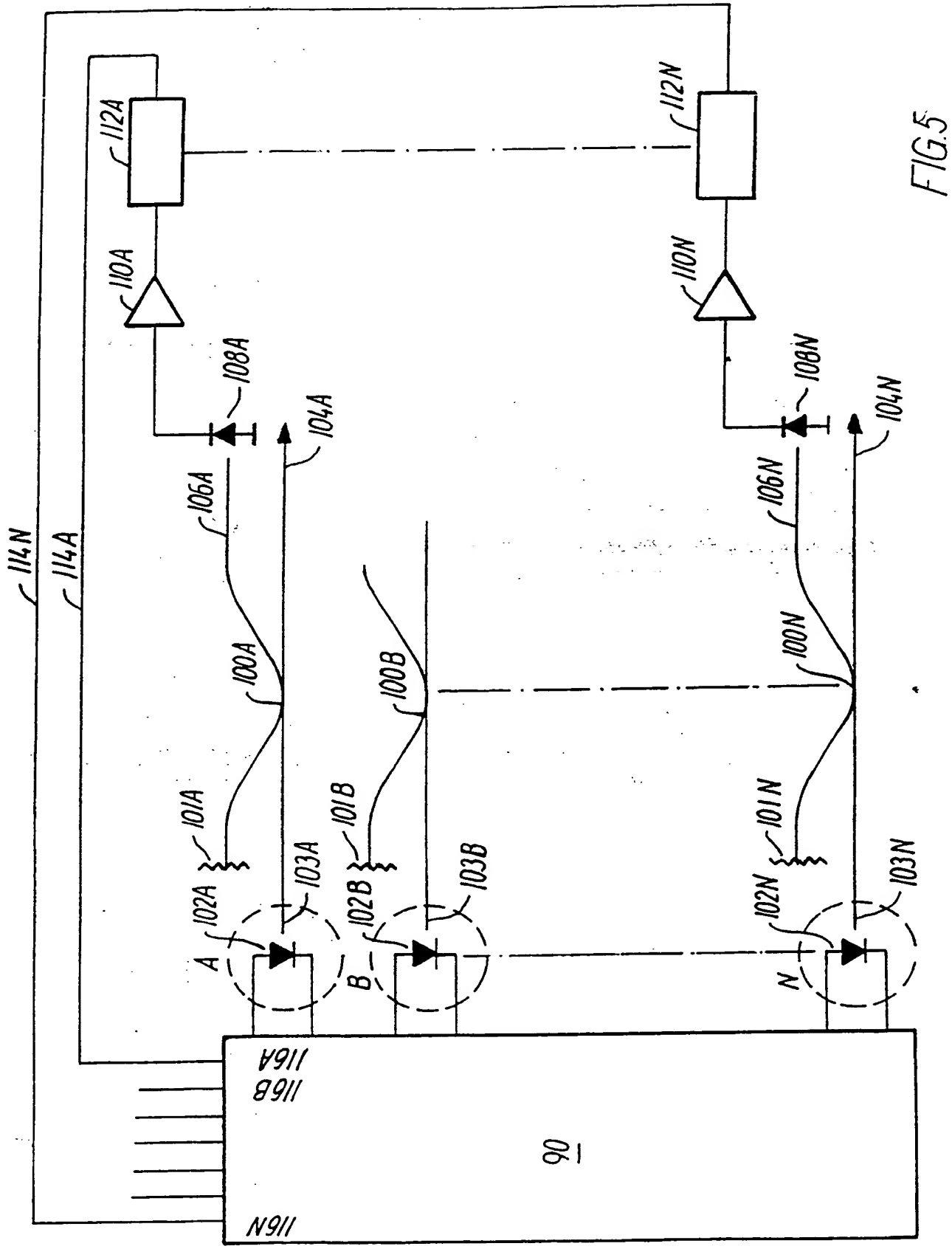
FIG.4


112A
112N
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110N
108A
108N
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104N
106A
106N
114N
114A
100A
100B
100N
101A
101B
101N
103A
103B
103N
102A
102B
102N
A
B
N
116A
116B
116N
90

FIG.5

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK 91/00267

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 04 B 10/12, H 01 S 3/07

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	H 04 B, H 01 S

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
Y	EP, A1, 0408394 (BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY) 16 January 1991, see column 5, line 58 - column 6, line 9	1
A	--	2-8
Y	EP, A2, 0339840 (AMERICAN TELEPHONE AND TELEGRAPH COMPANY) 2 November 1989, see column 11, line 25 - line 40; figure 8	1
	--	
Y	EP, A2, 0215711 (INTERNATIONAL STANDARD ELECTRIC CORPORATION) 25 March 1987, see page 2, line 18 - line 20; page 5, line 10 - line 12; figure 2	1
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IV. CERTIFICATION

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A	EP, A1, 0395277 (STC PLC) 31 October 1990, see the whole document	7-8

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		GB-A-	2236895	91-04-17
		WO-A-	91/01066	91-01-24
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		US-A-	4881790	89-11-21
EP-A2- 0215711	87-03-25	JP-A-	62061448	87-03-18
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